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Development of tungsten carbide based self lubricant cutting tool material: Preliminary investigation

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ABSTRACT

In the recent years, manufacturing industries show utmost attention toward clean technology. In the present work, self lubricated cutting tool material is developed for cutting fluid less machining. Tungsten carbide is considered as a basic cutting tool material, and cobalt and calcium fluoride are considered as a binder and solid lubricant respectively. In this work, the effect of milling time and the amount of solid lubricant on the material development is investigated. Particle size reduced with the increase in milling time up to 40 h and increased afterwards due to the agglomeration. Milled powders were compacted at various pressures and subsequently sintering was carried out. Effects of milling hours and compaction pressure on density and hardness were examined with the aid of a scanning electron microscope, a laser particle size analyzer, an X-ray diffraction analysis and the Rockwell hardness test. Various amounts of calcium fluoride were considered and the transverse rupture strength of sintered material was evaluated. Among the considered materials, 5 wt.% of calcium fluoride material exhibited superior strength over other investigated materials.

Introduction

Self lubricating materials are being used in practice for load bearing applications including bearings and gears. However, utilization of solid lubricant materials in the manufacturing industries is not yet established due to the limited data and incomplete understanding. Very few research works were carried out for the development of self lubricating material for machining application [1–4]. Deng et al. [1] developed an Al_2O_3/TiC ceramic cutting tool with a CaF_2 solid lubricant and evaluated the performance of the developed cutting tool. Deng et al. [2] evaluated friction and wear characteristics of developed Al_2O_3/TiC/CaF_2 composites under sliding friction. Investigation confirmed the reduction of friction and wear under sliding and machining. Deng et al. [3] developed a cutting tool by filling MoS_2 powders in the microholes at the rake and flank surfaces of the cemented carbides. Cutting forces, tool wear and coefficient of friction were evaluated. Al_2O_3 and TiB_2 powders were prepared via wet ball milling followed by hot pressing and sintering [4]. Machining was carried out and reduction of friction and wear was observed.

Hewitt and Kibble [5] utilized high energy ball milling and effects of milling time on the nanostructure of WC–Co composites are investigated. With increase in milling time, particle size reduces however; contamination also increases beyond particular milling hours. Iron contamination is the most common problem while milling tungsten carbide in a steel vial at very high milling speed [6]. Avettand et al. [7] investigated the milling characterization of tungsten carbide based materials and contamination after prolonged milling time was observed.

Upadhyaya and Bhaumik [8] sintered a WC–Co material and evaluated hardness and transverse rupture strength. Nickel was considered as a binder material; however cobalt exhibited a superior binding behavior. Sharifi et al. [9] developed and evaluated the mechanical properties of aluminum reinforced with boron carbide (5–15%). With the increase in boron carbide, hardness increases due to the presence of hard phase and reduction in particle size. Suzuki and Hayashi [10] studied the effect TiC (6–17%) in the tungsten carbide material. 6% TiC alloy exhibited a higher strength than that of 11 and 17%. Beyond this amount, TRS decreases due to the poor wettability. Deng et al. [11] studied the effect of solid lubricants, CaF_2, MoS_2 and BN (5–15%) contents on the flexural strength and hardness of Al_2O_3/TiC composites. The addition of solid lubricant decreases the hardness and flexural strength due to the formation of microcrack.

From the prior literature, it is observed that very few works have been reported on the development of solid lubricant cutting tool material. It is also observed that there is a need to understand milling, compaction and strength of the proposed solid lubricant cutting tool material. The main aim of the present work is to develop a tungsten carbide based solid lubricant material and to investigate the effect of ball milling time and the amount of solid lubricant material on the transverse rupture strength of the material.

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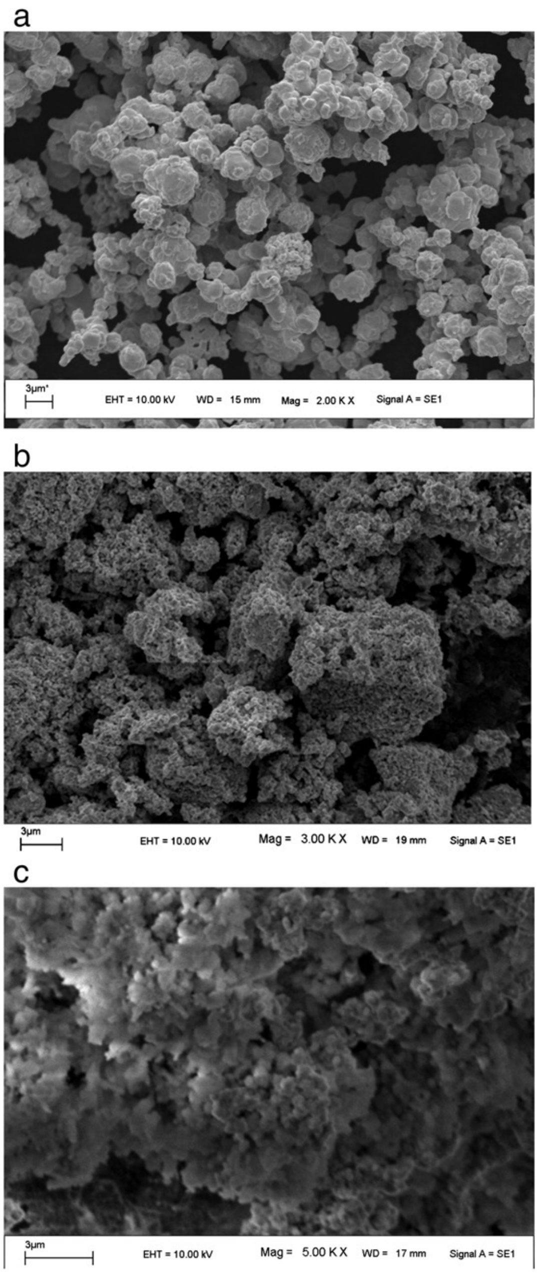

Fig. 1. a. Morphology of as received material (tungsten carbide). b. Morphology of as received material (cobalt). c. Morphology of as received material (calcium fluoride).

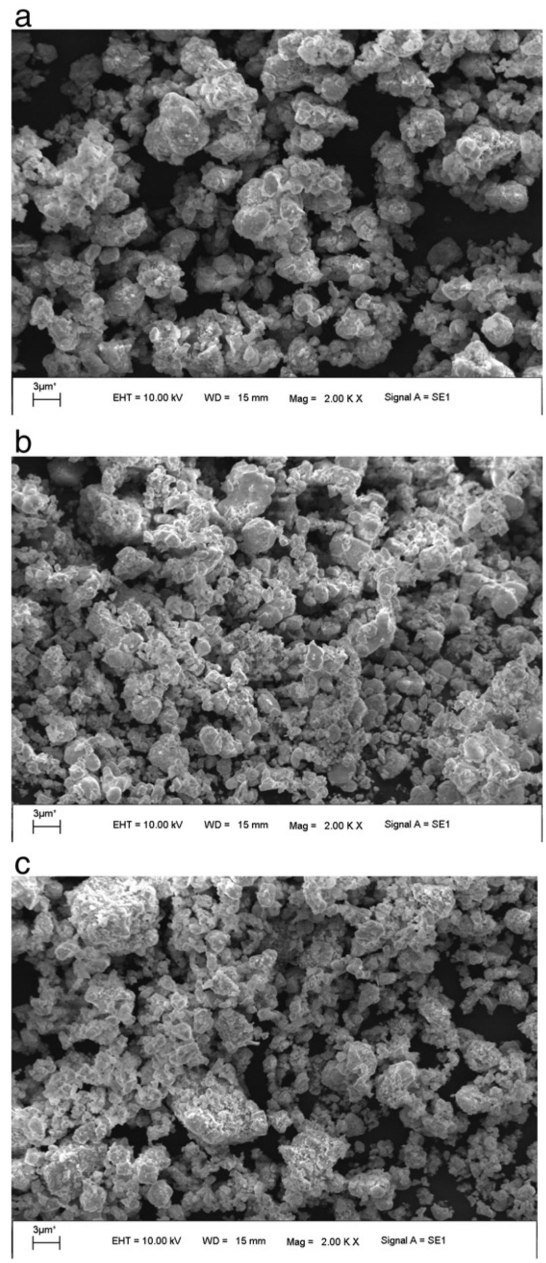

Fig. 2. a. Morphology of WC–10 wt.%Co–5 wt.%CaF_2 after 20 h. b. Morphology of WC–10 wt.%Co–5 wt.%CaF_2 after 40 h. c. Morphology of WC–10 wt.%Co–5 wt.%CaF_2 after 100 h.

Experimental procedure

Materials and processing

Tungsten carbide (WC) of 15–18 μm size with 99.8% purity (*Rapicut carbides*) is used as a basic cutting tool material due to its high hardness, good strength, and excellent wear resistance. Cobalt (Co) of 20–30 μm size with 99.5% purity (*Loba Chemie*) is used as a binder and 10 wt.% of Co is commonly used for the development of the WC based composite [5,12,13]. Among solid lubricants, calcium fluoride (CaF_2) of 170–180 μm size with 98% purity (*Loba Chemie*) is considered for cutting tool application due to the fact that it offers lubrication even at higher temperature [14]. Stearic acid of 1–5 wt.% is commonly being used [15] and 4 wt.% is considered for the present investigation.

Considered materials were milled in the planetary ball mill (Insmart system, PBM07) under a nitrogen (0.5 kg/cm^2) atmosphere. Plate speed and bowl speed are 90 and 207 rpm and the powder to ball ratio was taken as 1:5. Plate speed and powder ball ratio was decided to avoid contamination. WC was milled with 10% of Co and 5% of CaF_2 at 20, 40, 60, 80 and 100 h for the milling characterization. To understand the effect of solid lubricant on transverse rupture strength (TRS), various weight percentages (0, 3, 5, 7 and 10) of CaF_2 were considered and milled up to 40 h. Milled particles were characterized with the aid of a scanning electron microscope (SEM), a laser particle size analyzer (LPSA) and an X-ray diffraction (XRD).

Green compacted test specimens (40 × 16 × 5 mm) were compacted uniaxially in the pressure 200–400 MPa as per the ASTM B331-95 with the aid of tensile testing machine (UTE 20). Hewitt et al. [12] and Hewitt and Kibble [5] also developed a tungsten carbide based material by compacting milled powder in the range of 100–400 MPa. Subsequently test specimens were sintered in a tube furnace (Bysakh, Okay 70T7) under a nitrogen atmosphere (0.5 kg/cm^2) to avoid oxidation. During sintering, initially specimens were heated to 400 °C at the